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J. J. CHRISTENSEN AND H. C. H. KERNKAMP[1]

INTRODUCTION

The toxicity of scabby grain has been known for a long time in Russia and Eastern Siberia, where it was called "Mi-Chun" by the Chinese farmers, and the scab problem is of major importance to Russian peasants of these regions. The toxic qualities of the diseased grain are communicated to the flour and also to the bread which is known locally as "inebriant bread," or "intoxicating bread." Whenever such bread is eaten, symptoms of intoxication or poisoning result (8, 21).

In 1928 there was a severe epidemic of scab on barley, particularly in the corn-belt region of the United States. Following this outbreak of scab, there were numerous complaints from this country and from Europe regarding the harmful effects of feeding scabby barley to pigs. German investigators (2, 3, 11) found that much of the imported American barley when fed to swine caused a sickness characterized by nausea and vomiting, resulting in loss of body weight. Miessner and Schoop (11) examined 14 lots of American barley and found that those infected with *Gibberella saubinetii* (Mont.) Sacc. were toxic to pigs. Opperman and Doenecke (14) found that 25 out of 45 lots of American barley infected with *G. saubinetii* caused sickness in swine. Beller and Wedemann (3) noted that Fusarium-infected barley from America was distinctly distasteful to pigs.

As a consequence, American barley was rejected at certain European ports. On October 1, 1928, the German Ministry of Food and Agriculture issued a notification that barley coming from the United States (except that from Kansas, Oklahoma, Texas, and Colorado) must be tested for its toxicity before being admitted into the country (2).

A number of American investigators have made feeding tests with scabby barley and have found it injurious to certain animals. Roche, Bohstedt, and Dickson (19) report that pigs, horses, and dogs are very

[1] Cooperative investigation between the Division of Plant Pathology and Botany and the Division of Veterinary Medicine.

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sensitive to substances produced in scabby barley and can not tolerate even low percentages of badly scabbed kernels. Ruminants and poultry made good gains when fed similarly infected barley. Roche and Bohstedt (18) reported that scabby barley was not injurious to lambs and ewes, whereas oats, with 70 per cent infection, were unpalatable to horses. In 1930 Mundkur and Cochran (13) found that pigs fed an exclusive diet of heavily scabbed barley developed nausea and starved rather than eat it. Young chicks fed scabby grain developed rough plumage and lost weight, while mature chickens showed no ill effects. In 1934 Mundkur (12) found that pigs lost weight when fed badly scabbed barley. This barley, when fed to pigs, caused vomiting and evidences of slight intoxication. Mains, Vestal, and Curtis (10) also found scabby barley distasteful and injurious to swine. When the pigs were fed barley containing from 35 to 58 per cent scabby kernels, they lost weight and ate only enough to avoid starvation. However, these writers observed no cases of vomiting. Cattle were able to utilize successfully barley with 58 per cent infection when it was fed to the extent of 50 per cent of their grain ration. Such barley when used at the rate of 20 per cent of the grain ration proved as palatable to chicks as non-scabby barley.

Dickson (5) made a number of feeding experiments with scabby barley and has shown that it affects pigs in the following manner: (1) a reduced appetite and feed consumption; (2) a more or less disturbed digestive system; (3) vomiting if the grain was badly infected. Dickson states that small pigs were actually killed by overdoses of purified extract. He concluded that scabby barley with 2 to 3 per cent infected kernels by weight should not be used for feeding pigs. It required about 25 per cent more grain to produce a pound of gain in weight with medium scabby barley than with clean barley. Rainio (16) in Finland found that oats heavily infected with *Gibberella saubinetii* were harmful to pigs and horses. Oats with 10 to 20 per cent infections were unpalatable, and samples of oats with a higher percentage of infection were rejected or eaten reluctantly and caused digestive disorders. Even cattle showed a loss of appetite when the infection exceeded 20 per cent.

In general, the work of these investigators has shown clearly that barley and oats heavily infected with *Fusarium* spp. are undesirable as feed for pigs and horses. Their feeding tests proved that pigs became sick or actually starved rather than eat the Fusarium-infected grain. However, there are only meager data on the amount of infected grain that renders the barley unpalatable for swine, or on the percentage of infected seed they will tolerate and still make satisfactory gains in body weight. Furthermore, there is virtually no information on the toxicity of blighted grain caused by fungi other than *Fusarium*. Likewise, no study has been made on the influence of the association of *Fusarium, Helminthosporium, Alternaria,* and other fungi and bacteria common on diseased barley seed. In some years, as in 1932 and 1933, much of the barley in certain regions of Minnesota was more or less blighted by a miscellaneous group of fungi and bacteria. On the market the price of such barley usually is considerably reduced, chiefly because it has been considered unfit as food for swine; hence, a thoro investigation of this problem is of considerable practical and economic importance.

NATURE OF THE TOXIC PRINCIPLE OF SCABBY BARLEY

The chemical formula of the toxic substance has not been determined. However, it is water-soluble and thermostable.

In 1929 Danckwortt (6) made a chemical analysis of a number of samples of scabby barley from America. He obtained a slightly higher amount of ammonia, sulphuretted hydrogen, and amines than in the normal lots, whereas tests for hydrocyanic acid and alkaloids were negative.

Popp (15) attributed the toxic principle to partial disintegration of the carbohydrates and albumins from which toxalbumins or toxic nitrogenous compounds are formed.

Schroeter and Strassberger (20) were of the opinion that the toxic principle was cholin or readily hydrolysable fatty acid esters of cholin. These compounds were present in scabby grain in an abnormally large quantity.

Dickson, Link, Roche, and Dickson (7) were able to free the crude extract of scabby barley from some of its foreign material and thereby increased its potency as an emetic. They concluded that the active substance was associated with fractions containing glucosides or basic nitrogen compounds. More recently, Dickson (5) has pointed out that there is an accumulation of glucose in scabby kernels. Sometimes the increase is 200 per cent over that of clean barley. The formation of proteins was arrested and modified, resulting in a marked increase in water-soluble nitrogen. There also was an increase in the amount of fatty acids and in their rancidity.

ETIOLOGY

"Blight," a term adopted in 1933 (23) to cover a group of diseases of barley grain, is characterized by shriveled and discolored kernels (Fig. 1). "Scab" is the name given to that type of kernel blight caused by species of *Fusarium.*

In northern Russia much of the so-called "inebriant bread" is attributed to the action of *Fusarium avenaceum* (Fr.) Sacc., while in southern Russia and Finland *F. graminearum* Schwabe is usually associated with the scabby grain (8, 16, 21). The latter organism is by far the most prevalent one in Minnesota and other sections of the United States where scab of cereals is important. There are more than a dozen species of *Fusarium* that cause blight of barley grains (1, 22); however, their relative ability to produce the toxic principle is not known. The geographic distribution of these species may vary considerably (1). In the United States scab of barley and other small grains is most important in the central and eastern states, particularly in the corn-belt region, where 30 or more inches of rainfall occur annually. In Minnesota scab is most common and destructive in the southern part of the state.

FIG. 1. BLIGHTED BARLEY
Left: Scabby barley. Right: Sound barley.

The scab organisms overwinter primarily on cornstalks, barley and wheat stubble, straw, and other organic residues. Cornstalks are a favorable substrate for the production of both conidia and ascospores. The conidia are asexual spores produced on the surface of the stalks, while the sexual ascospores are borne in small black fruiting bodies, perithecia (Fig. 2). There is usually an abundance of inoculum at the time barley begins to head, and during the blossoming period or shortly thereafter it is most susceptible to infection and injury.

Helminthosporium, Alternaria, and a great many fungi other than *Fusarium* and bacteria may cause barley blight. These organisms, with the exception of *Helminthosporium* spp., do not appear to cause marked shriveling of the seed but rather cause discoloration of the hull and the caryopsis. During 1932, 1933, and 1934 *Alternaria* was the most common organism isolated from barley grain produced in Minnesota (4).

It frequently happens that small, undeveloped kernels are attacked by these semi-parasitic organisms, and consequently they appear as if shriveled by pathogens when, as a matter of fact, they are only discolored. The various organisms commonly associated with blighted kernels overwinter on the seed and plant remains and in the soil. Under favorable conditions they grow saprophytically, and some, like certain species of *Helminthosporium,* may attack the roots and foliage of cereals and grasses. The symptoms produced on the grain by the blight organisms are so similar in most seasons that the causal organism can not be determined readily except by laboratory methods. Furthermore, the symptoms may vary considerably with prevailing weather conditions. Often the grain is not blighted by a single fungus, but by groups of fungi and bacteria, the proportions of which may modify the symptoms. Only in certain years, as in 1928 and 1935, is it possible to recognize scabby barley with certainty. The gray-brown discoloration of the kernels, the shrunken kernels which are frequently coated with a pinkish growth of spores and mycelium, and the presence of scattered masses of perithecial stromata indicate that the grain is scabby (Fig. 2).

Rainfall is the most important meteorological factor influencing the

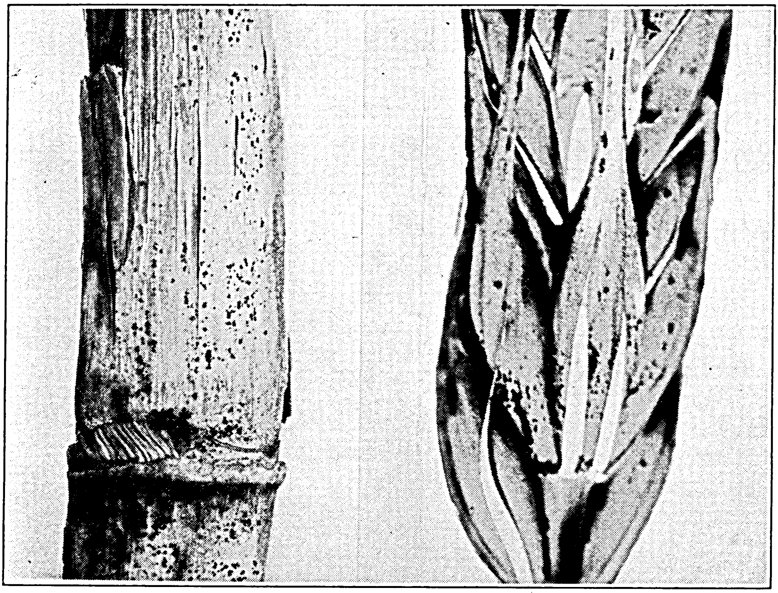

FIG. 2. PERITHECIA OF *Gibberella saubinetii*
Left: On corn stalk. Right: On barley kernels.

type and degree of infection. If the infection occurs early in the development of the kernels and during periods of moist weather, the kernel is overrun by the fungi and becomes discolored and severely shrunken.

When the infection is caused by *Fusarium* spp., the chemical composition of the kernels is materially altered, and a toxic substance is produced, the potency of which depends on time and severity of infection.

ISOLATION OF MICRO-ORGANISMS

Since one can not determine by visual inspection the percentage of infected kernels, or the proportion of blighted grain infected by the different organisms, it is necessary to make plating tests on nutrient media. Obviously, this is essential when making toxicity studies. The method used in this study was identical with that previously described by Christensen and Stakman (4).

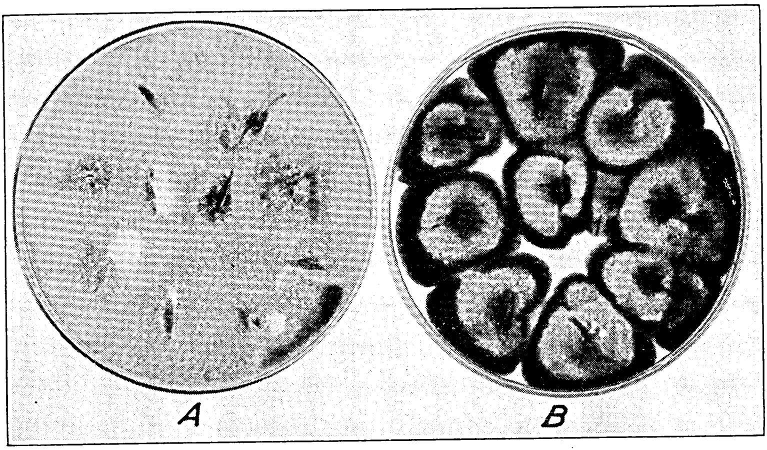

FIG. 3. COLONIES OF *Fusarium* spp. AND *Helminthosporium* spp. DEVELOPING FROM ARTIFICIALLY INOCULATED SEED PRODUCED UNDER A MUSLIN TENT IN THE FIELD
A. *Fusarium* spp. B. *Helminthosporium* spp.

The seeds were selected at random, either from the whole sample or from the blighted portion, dipped in 70 per cent alcohol, soaked in corrosive sublimate solution for two to three minutes, and then washed in 50 to 75 per cent Laborreque's solution of sodium hypochlorite. The seeds were then placed on acidified potato-dextrose or sucrose agar in petri dishes. Identifications were made when colonies of the fungi developing from the seeds were about 2 cm. or more in diameter (Fig. 3). Two to six hundred seeds usually were plated from each sample. To eliminate error due to variation in the medium, temperature, and differences in the disinfectant, seeds from each sample were plated at different times. The results of the isolation studies are summarized in the tables giving results of feeding trials. (See Tables 4, 5, and 6.) In general, the results indicate, as has been previously shown (4), that many fungi are associated with blighted barley. Miessner and Schoop (11) and Richter (17) also found a number of different organisms present on diseased barley seed.

POTENCY OF WATER EXTRACTS OF SCABBY GRAIN

The fact that water extracts prepared from scabby barley contain substances that are toxic when placed in the stomachs of swine is definitely known. The writers have often administered such extracts to swine with the result that vomiting was induced. This symptom is considered a reliable biologic criterion of the toxicity of the material when placed in the stomach of a fasted pig. There is little information regarding the amount of scabby barley required to induce vomition.

The extracts were prepared by soaking diseased kernels of barley in water. Originally, this was done by first grinding the barley and then soaking it in clean water for two or three days. In the later tests the grinding was omitted, as it was found unnecessary. After the soaking period, the solid portion was removed by filtering through several layers of cheesecloth. The extract was standardized on the basis of the amount of barley used per cubic centimeter of liquid. The administration in all cases was effected by passing a rubber tube (stomach tube) into the stomach, via the mouth, pharynx, and esophagus, thus depositing the test liquid (extracts) directly and definitely in the stomach. The quantity of the liquid administered varied between 200 and 800 cc. depending upon the size of the pig.

The samples of barley used for the quantitative or dose studies were obtained from barley artificially inoculated with *Fusarium* spp. while growing under muslin tents. The kernels were uniformly diseased, and the bushel weight was approximately 24 pounds. Plating tests indicated that approximately 100 per cent of the kernels were infected with *Fusarium* (Fig. 3A). Only a very small percentage of the kernels germinated, and practically every kernel floated on water. It is doubtful whether a more heavily infected lot could be secured. The summarized data on these tests are included in Table 1.

The minimum amount of the above scabby barley required to induce vomition was about 13 grams (0.46 oz.). However, the 132-pound pig which received this amount vomited only once, and this not until 34 minutes after the administration. The extracts prepared from 12 and 10 grams of the diseased barley failed to induce the symptom-complex in pigs that weighed 60 and 90 pounds, respectively. The extracts prepared from 15 (about 0.52 oz.) and more grams of scabby barley consistently caused the pigs to vomit. On the other hand, the extracts made from 50 and 200 grams of sound barley did not cause vomition. They were non-toxic. The results further indicate, in general, that the lapse of time between the administration of the toxic substance and the first vomition depends upon the concentration of the extract and the size of the pig. There was, of course, some variation in the reaction among the individual pigs on the same day and with the same pig on different days.

Table 1. Amount of Scabby Barley* Required to Cause Toxic Symptoms (Vomiting) in Pigs

Amount of scabby barley† (in grams)	Weight of pigs (in lbs.)	Time (minutes) between feeding and vomiting	Number of times pig vomited
500	90	13	14
200	90	14	18
200 (clean)	90	.....	0
40	100	17	11
30	110	38	8
30	115	16	6
20	90	24	2
17	49	23	6
17	149	18	7
17	60	?	3
15	45	19	8
13	132	34	1
12	60	.....	0
10	90	.....	0
50 (clean)	45	.....	0

* Water extracts administered per orum via stomach tube.
† Virtually 100 per cent scabby barley, weighing about 24 lbs. per bushel.

As would be expected, the number of times a pig will vomit bears some relation to the size of the dose administered. One pig that received the extract from 200 grams of scabby grain vomited 18 times within 27 minutes, while another pig of the same weight, receiving one-tenth the amount of extract, vomited only twice.

The minimum dose also varies considerably, depending upon the degree of scab infection. There is a direct correlation between the amount of the toxic principle present and the severity of the infection as measured by the degree of shriveling of the kernels and by the presence of the fungus growth in and on the infected kernels. Thus, when the distinctly scabby grains were divided into two classes, based on weight and size of kernels, it required about twice as much extract from the heavier sample to induce vomition as from the lighter one. In general, other tests with the same and different materials gave similar results.

The potency of the toxic principle also was determined by injecting pigs hypodermically with sterile water extracts from scabby barley. In these tests the extract was made from naturally infected barley with approximately 50 per cent blight by weight and with about 80 per cent of the kernels infected with *Fusarium* spp. The extract was so standardized that 1 cc. of liquid was equivalent to the amount of toxic principle obtained from 1 gram of barley soaked for 48 hours. One pig received 1 cc. of the extract intravenously, one 5 cc. intraperitoneally, and another 3.5 cc. intraspinally. The first two pigs sickened, but only the one injected intraperitoneally vomited, twice within 45 minutes. The pig receiving the intraspinal injection showed no ill effect during the four hours it was under observation.

ATTEMPTS TO PRODUCE THE TOXIC PRINCIPLE IN ARTIFICIAL CULTURE

Miessner and Schoop (11) reported that the symptoms induced by feeding pigs pure cultures of *Gibberella saubinetii* resembled those following the consumption of naturally infected barley. Mains, Vestal, and Curtis (10) found that pigs fed pure cultures of *G. saubinetii* grown on autoclaved barley and mixed with sound barley immediately ceased gaining and eventually lost in body weight. The pigs did not become sick, but failed to consume the normal amount of feed. Feeding tests made by Mundkur (12) indicated that artificially infected barley grain was more injurious to chicks than naturally infected barley. Popp (15), however, concluded that pure cultures of *G. saubinetii* were not toxic.

Obviously, if the toxic principle can be produced readily on artificial media, it would greatly simplify experimental feeding tests. It would then be possible to add definite percentages of scabby material to sound barley or other foodstuffs and determine the tolerance and symptoms accurately. Furthermore, the relative amount of toxin produced by different species or physiologic forms of *Fusarium* could be ascertained. Therefore, tests were made to determine whether the toxic principle was produced in artificial cultures of *Fusarium* in sufficient quantities for feeding tests.

A number of organisms were grown on different substrata. *Fusarium* spp. were grown in liquid nutrient media, on solid nutrient agar, on steamed and unsterilized barley kernels, on green barley leaves, and on young spikes of barley. The results are summarized in Table 2.

The pigs were given from 200 to 500 cc. of the extract, depending on the weight of the pigs, which varied from 34 to 100 pounds. None of the pigs vomited, and none of them showed any symptoms of distress; whereas a water extract from 30 grams of naturally infected, virtually 100 per cent scabby grain (used as a control) produced frequent vomiting. These results indicate that *F. graminearum* and certain other fungi do not produce the toxic principle when grown on artificial media or on mature barley grain. The toxic principle is associated with naturally infected grains and is produced during the formation of the kernel.

Table 2. Summary of Attempts to Produce a Toxic Principle Harmful to Pigs by Growing *Fusarium* spp. and Other Fungi on Various Substrates

Source of extract	Results following administration*
Gibberella saubinetii grown on nutrient agar	Negative
Gibberella saubinetii grown in liquid medium	Negative
Bacteria, *Alternaria, Helminthosporium* and many other fungi, except *Fusarium,* isolated from blighted barley and grown on nutrient agar	Negative
200 grams of unsterilized barley seed inoculated with *Fusarium* spp. cultures five days old	Negative
Same as above except barley, sterilized before inoculation	Negative
Same, but culture 10 days older	Negative
200 grams of sterilized wheat germs inoculated with *F. graminearum* and *F. culmorum*	Negative
Shoots from germinating barley inoculated with *Fusarium* spp. and incubated in moist chamber for 5 days	Negative
Heads of barley in late milk stages clipped off, inoculated with *Fusarium* spp. and incubated in moist chamber for about 7 days	Negative
Control (30 grams of naturally infected scabby kernels)	Repeated vomiting

* Water extract administered per orum via stomach tube.

Other tests, however, clearly proved that pure cultures of certain organisms grown on barley grain are decidedly distasteful to pigs. Mason jars containing sterilized sound barley were inoculated separately with *Alternaria, Chaetomium, Helminthosporium, Fusarium* spp., *Penicillium* spp., and bacteria. After two weeks' growth, each culture was thoroly mixed with 50 per cent of the usual balanced ration and then fed to hungry pigs. Altho the pigs refused to eat the pure cultures, the rations containing the admixture of the respective cultures were consumed rather reluctantly. However, the pigs did not sicken or vomit.

Ergot also may render barley unpalatable. Johnson and Palmer (9) found that grain containing 0.5 per cent ergot by weight was distasteful to pigs.

TESTS WITH WATER EXTRACTS FROM BLIGHTED GRAIN

During 1932, 1933, and 1935 a number of farmers sent in samples of barley which they reported unpalatable to swine. In several samples the percentages of blight by weight were determined by the Federal Grain Supervisor, United States Department of Agriculture, Minneapolis, Minnesota. The amount of blight ranged from less than 1 per cent to 32 per cent by weight. In most cases the samples contained a rather high percentage of kernels infected with *Fusarium, Helminthosporium,* and *Alternaria,* and many other fungi and bacteria, as determined by plating tests. The 1935 samples contained a much higher percentage of seed blighted by *Fusarium* spp.

Toxicity tests were made with seven of these samples. The results are given in Table 3. Extracts of three samples, Lots 4, 6, and 7, induced vomiting. Altho Lot 4 contained fewer blighted kernels than Lots 2 and 3, it caused vomiting, while Lots 2 and 3 did not. Extracts of Lots 2 and 3 were made from grain containing 36 and 39 grams of blighted kernels, respectively. Therefore, the extracts should have contained two to three times the amount of toxic principle necessary to induce vomiting. Furthermore, these samples also had a relatively high percentage of kernels partially blighted but not designated as "scabby." Plating tests of the kernels from sample No. 2 on potato-dextrose agar indicated that 47 per cent of all kernels were infected with *Fusarium* spp., primarily *F. graminearum,* and the remainder with other fungi and bacteria. The presence of a fairly large proportion of sound kernels in the sample apparently counteracts the effect of the toxic principle.

Table 3. Results of Administering Water Extracts* From Lots of Barley Reported by Farmers as Being Distasteful to Pigs

Lot No.	Amount of barley (in grams)	Barley grade	Percentage of blight† (by weight)	Number of times pig vomited
1	200	Sample scabby	3.8	0
2	675	do	5.4	0
3	675	do	7.4	0
4	675	do	4.0	1
5	675	do	3.5	0
6	400	Sample blighted	32.0	11
7	600	No. 4 blighted	9.7	11
8	30	Control sample (scabby)	97.0	10

* Water extract administered per orum via stomach tube.
† Determined by Federal grain supervisors.

Water extracts of Lots 6 and 7 of the 1935 crop proved very toxic, as the pigs to which they were administered became quite sick and vomited many times. It is significant that an extract from 100 grams of Lot 6 induced one pig to vomit 5 times, while that from 50 grams caused another pig to vomit twice, but the extract from 25 grams was not injurious. Incidentally, the grower of this lot had over 500 bushels of the scabby barley. The barley (Lot 6) had a rancid and musty odor and contained 32 per cent by weight of distinctly blighted kernels. After being soaked in water, more than 90 per cent of them were completely or partially discolored. Plating tests of the grain on acidified nutrient agar proved that virtually every kernel was infected by fungi, about 70 per cent of them by *Fusarium*. However, when the seeds were sown on an alkaline agar many kernels gave rise to bacterial colonies. It is possible that the extreme potency of this lot of barley is associated with the combined action of *Fusarium* and bacteria. It is rather doubtful if barley so heavily infected has any value as food for swine when fed alone or when mixed with clean grain in such proportions that no harmful effects are apparent.

Toxicity tests were made with water extracts from five additional lots of barley having different percentages of blight by weight, grown in southern Minnesota in 1935. Each lot originally consisted of two pounds of barley which was immersed in water and stirred thoroly. The light and severely blighted kernels floated and were skimmed off and used in making the extract. The extract from each lot induced the pigs to vomit many times. Another pig was given the extract of 600 grams of scabby barley (Lot 7) that contained at least 25 times the concentration of the toxic principle required to induce vomition. The pigs became sick and vomited many times but fully recovered within a few hours.

A few toxicity tests were made with scabby wheat and moldy corn. An extract of naturally infected wheat obtained from Mr. R. Huntsinger, County Agricultural Agent in Jackson County, caused repeated emesis when it was administered to a pig. An extract from 30 grams of scabby wheat heads produced by inoculating plants growing under muslin tents at University Farm, St. Paul, Minnesota, was sufficient to cause a pig weighing about 100 pounds to vomit several times. Water extracts were made from two collections of moldy corn, consisting of 170 and 400 grams, respectively. The two pigs that received these extracts sickened and developed the symptoms characterizing the syndrome produced by Fusarial toxin. The causal organisms involved were not determined definitely, altho *Fusarium* spp. were common.

In order to ascertain whether *Fusarium* spp. rendered corn harmful to swine, tests were made with artificially inoculated corn. Young, growing ears were inoculated hypodermically with pure cultures of *F. graminearum.* The kernels became severely infected, and the organism developed abundantly in the husks. An extract was made from 170 grams of diseased kernels and also from portions of the infected husks. These extracts were administered to two pigs weighing about 35 pounds and 50 pounds, respectively. Both pigs became sick, vomiting 19 and 5 times, respectively, within one hour and 22 minutes; both died within the next 20 hours. A necropsy disclosed a marked hemorrhagic inflammation of the stomach and small intestine, a gastroenteritis.

FEEDING TESTS

Naturally Infected Grain

During 1932 and 1933, when much of the barley in certain regions of the Northwest, especially in Minnesota, was considered scabby or blighted, many inquiries were made in regard to the suitability of such barley as food for swine. Because many reports indicated the injuriousness of blighted barley when ingested by livestock, swine in particular, pigs were fed experimentally with infected grain. Twenty-seven groups of swine were used in the tests. Most of the samples of barley fed were obtained from Mr. O. Zimmerman, of the State Board of Grain Appeals, Minneapolis, Minnesota. The samples, about three or four bushels each, contained different percentages of blight.

The first tests were made with 13 groups of pigs, two in each group, the ration consisting of barley, so that the full effect of any toxic substances could be observed and studied. The barley was ground and fed dry, and the pigs were allowed all they desired. Water was available at all times. The pigs were confined to indoor pens throughout the feeding test periods. The barley feeding was begun after a fast period of 24 hours. The percentage of kernels infected with *Fusarium, Helminthosporium,* and other fungi and bacteria was determined as previously indicated. The barley samples used in this test were representative of the 1932 crop. The results are summarized in Table 4.

The first and most important observation made on this series of feeding tests was that in no case was there evidence of any direct injurious or harmful effects. In other words, none of the animals became sick as a consequence of their ingesting the blighted barley. Particular attention is called to Group 13. The two pigs comprising this group averaged 147.5 pounds at the beginning of the feeding period and 155.2 at the close of the period, 11 days later. These pigs were fed a sample grade of scabby barley containing 5.4 per cent of blighted kernels by weight, 47.0 per cent of the seeds being infected with *Fusarium.* The pigs consumed an average of 3.96 pounds of the barley a day and averaged 0.34 pound gain in weight per pound of food consumed. This is a satisfactory gain, being 17.6 per cent more than the best gain per pound feed consumed by those receiving virtually blight-free barley (Group 6). The pigs in Group 5 were fed barley that weighed 48.5 pounds to the bushel but contained 5.6 per cent of blighted kernels by weight, 12 per cent of the seeds being infected with *Fusarium.* Twenty-one days was the duration of feeding. The average daily gain was 0.96 pound, and the gain per pound of food consumed was 0.22 pound, a fairly satisfactory result for an exclusive barley ration. In general, similar results were obtained with other samples of barley that had been graded scabby and where the percentage of Fusarium-infected seeds varied from 2 per cent to 10 per cent.

The pigs in Groups 7 and 8 were fed needles[2] from scabby and clean barley, respectively. The barley weighed only 40 pounds per bushel. The needles from the scabby barley contained 20 per cent oats. The blight for this sample equaled 24 per cent by weight and 10 per cent of the seeds were infected with *Fusarium.* The duration of the feeding period was 21 days. The average daily gain for the pigs receiving the needles from the blighted barley was 0.33 pound, as compared to 0.83 pound for those getting needles from the clean barley. The average daily food consumed was not very different, Group 7 consuming 3.19 pounds, Group 8, 3.79 pounds. The gain per pound of feed consumed for Group 7 was 0.09 pound, for Group 8, 0.21 pound. The feeding value of the needles from the blighted barley was decidedly inferior to that of the needles from clean barley.

Three groups of pigs (2, 6, and 10) were used as controls. The barley they received was virtually free from blight or scab. It weighed 45 pounds to the bushel and when plated on agar showed only a trace of *Fusarium* and 1.0 per cent infection by *Helminthosporium.* The average daily gain and gain per pound of feed consumed was fair to good for two groups (2, 6) but only fair to poor for Group 10. The ration or diet of these groups, as of those receiving the blighted barley, was not supplemented with any other foodstuff.

Gains in body weight and consumption of food were not particularly different for pigs fed clean barley than for those fed blighted barley, showing that blighted barley with a low percentage of scabby kernels is not dangerous as food for swine.

In 1933 isolations from hundreds of barley samples from the Northwest proved that much of the barley blight was caused by *Alternaria, Helminthosporium,* or bacteria, rather than by *Fusarium* (4). Millions

[2] "Needles" is a term applied to slender but not fully developed kernels separated in the process of screening.

Table 4. Feeding Tests With Pigs, Using Exclusive Diets of Blighted or Clean Barley from the Crop of 1932

Feeding test or group number	Number of pigs used	Average initial weight of pigs (in lbs.)	Barley grade*	Weight per bu.	Percentage blight by weight	Percentage seeds infected† *Fusarium*	*Helminthosporium*	Other fungi and bacteria	Duration of test in days‡	Average daily gain per pig (lbs.)	Average daily feed consumed per pig (lbs.)	Gain per pound feed consumed
1	2	74.5	Sample scabby	44.0	3.0	10.0	30.0	60.0	14	0.96	3.25	0.30
3	2	64.5	do	45.5	2.9	2.0	35.0	62.0	27	0.82	3.35	0.23
4	2	95.0	do	45.5	3.8	10.0	10.0	80.0	27	0.80	3.86	0.26
5	2	90.7	do	48.5	5.6	12.0	16.0	71.0	21	0.86	3.87	0.22
9	2	113.0	do	47.5	2.6	2.0	46.0	52.0	21	1.20	4.21	0.28
13	2	147.5	do	....	5.4	47.0	4.0	49.0	11	1.42	3.96	0.34
11	2	115.2	Special No. 2	48.5	0.6	8.0	16.0	71.0	14	0.71	4.26	0.16
12	2	151.7	do	47.0	0.9	4.0	25.0	70.0	14	0.58	4.00	0.14
7	2	116.2	Needles from scabby barley (20% oats)	40.0	24.0	10.0	11.0	67.0	21	0.33	3.19	0.09
8	2	90.5	Needles from clean barley	40.0	Tr.	Tr.	1.0	66.0	21	0.83	3.79	0.21
2	2	88.5	Clean (control)	45.0	0.0	Tr.	1.0	....	27	0.85	3.49	0.23
6	2	122.0	do	45.0	0.0	Tr.	1.0	....	21	1.40	3.95	0.28
10	2	131.5	do	45.0	0.0	Tr.	1.0	....	14	0.71	4.28	0.16

* According to Federal Grain Supervisors.
† Random sampling.
‡ Limited to amount of barley available.

Table 5. Feeding Tests With Pigs, Using Diets of 10 Parts Tankage and 90 Parts Blighted or Clean Barley from the Crop of 1933

Feeding test or group number	Number of pigs used	Average initial weight of pigs (in lbs.)	Barley grade*	Weight per bu.	Percentage blight by weight	Percentage seeds infected†			Duration of test in days‡	Average daily gain per pig (lbs.)	Average daily feed consumed per pig (lbs.)	Gain per pound feed consumed
						Fusarium	*Helminthosporium*	Other fungi and bacteria				
14	2	34.0	Clean (control)	49.0	0	Tr.	Tr.	......	18	1.27	3.01	0.40
17	3	88.0	Sample blighted	47.0	31	10	15	75	11	1.03	3.29	0.31
19	3	73.3	Clean (10% needles)	45.0	0	Tr.	Tr.	......	14	1.22	3.51	0.36
21	3	58.6	Sample blighted	44.0	20	4	15	81	18	1.11	3.10	0.37

* According to Federal Grain Supervisors.
† Based on plating 200 seeds on nutrient agar.
‡ Limited to amount of barley available.

of bushels of barley were blighted; hence the loss to farmers would have been enormous if the barley had been unsuitable as food for swine. Two samples of heavily blighted barley from the crop of 1933 were secured and fed to swine (Table 5).

Group 21, consisting of three pigs having an average weight of 58.6 pounds, was fed for 18 days on a barley graded as blighted and that weighed 44 pounds to the bushel. This sample contained 20 per cent blighted kernels by weight, and 4 per cent of the seeds were infected with *Fusarium,* 15 per cent with *Helminthosporium,* and 80 per cent with *Alternaria* and other fungi. The ration consisted of a mixture of 90 parts barley and 10 parts of 40 per cent meat meal tankage added to increase the protein constituents. The feeding was conducted as outlined above. Group 17 received barley that weighed 47 pounds to the bushel, with 31 per cent of blighted kernels. Plate cultures of this sample showed 10 per cent *Fusarium,* 15 per cent *Helminthosporium,* and 75 per cent other fungi and bacteria. This barley, as in the case of Group 21, was mixed with tankage and fed for 11 days to 3 pigs averaging 88 pounds in weight at the beginning of the test.

The most important observation from these two feeding tests, as in those when samples of the 1932 crops were used, is that none of the pigs showed any signs of sickness from eating the blighted barley. The amount of food consumed daily per pig was slightly less than the amounts consumed in the earlier tests, whereas the average daily gain and gain per pound of food consumed were somewhat greater. In fact, they were practically equal to those made by the pigs fed clean barley, the controls, Groups 14 and 19. The more favorable gains were, no doubt, due to the supplemented protein in the ration.

To obtain still further information on the effects of feeding blighted barley to swine, samples of diseased barley from Illinois, Iowa, and Minnesota, furnished by Prof. J. G. Dickson of the University of Wisconsin and agent in Cereal Investigations, U.S.D.A., were fed to six groups of pigs. There were two lots of barley from each state, with different percentages of blight.

The percentage of seeds infected with *Fusarium* varied but little in the samples from the different states, and most of the seeds were discolored by fungi other than *Fusarium* and *Helminthosporium,* as shown by plating tests. *Helminthosporium* spp. were two to three times more prevalent than *Fusarium* spp.

Table 6 gives the summarized results of the feeding tests with these samples of barley. The feeding tests were carried on according to the plan followed in the previous series, i.e. where the ration is composed of 90 parts barley and 10 parts tankage. The average daily gains and gains per pound food consumed were, excepting Group 24, quite satisfactory. The pigs comprising Group 24 were quite small and not a particularly good type of feeder pig. Group 24 was fed barley with 4.8 per cent blight by weight; however, only 2 per cent of the seeds were infected with *Fusarium* and 6 per cent with *Helminthosporium.* The same percentage of blighted barley was fed to Group 23 where 6 per cent of the seeds were infected with *Fusarium,* and 14 per cent with *Helminthosporium,* but the average daily gain was about 25 per cent greater, altho less than 0.2 per cent more food was consumed per pig per day. In other words, the difference appears to rest more with the pigs than with the food they ate. However, the significant fact was that in no case were the pigs injured as a result of consuming the blighted barley.

Artificially Compounded Scabby Samples

In the feeding tests described above, naturally infected samples of blighted barley were used. However, when such samples are used, there is no reliable method of knowing just what percentage of the seeds are partially blighted; hence the amount of the toxic principle actually consumed when such barley is eaten is not known. It was believed that a more accurate method for determining the amount of scabby barley the pigs will tolerate would be to add definite amounts of diseased grain to sound barley. Barley mixtures therefore were prepared by adding 2.5 per cent, 5.0 per cent, and 10.0 per cent scabby kernels by weight to respective samples of clean, sound barley. In order to equalize somewhat the quality and weight of comparable lots of barley, proportionate amounts of needles from disease-free barley were added to the sound barley. Ninety parts of the barley mixture and 10 parts of tankage constituted the ration. Three pigs were placed in each group. The summarized data appear in Table 7.

The data in Table 7 show that the pigs receiving the ration having 2.5 and 5.0 per cent of scabby barley (Groups 15 and 16) made a slightly greater daily gain and gain per pound of feed consumed than those that received the scab-free ration (Group 18). Group 20, on the other hand, receiving the ration containing 10 per cent scabby barley kernels, consumed only 2.49 pounds of feed per pig per day and made an average daily gain in weight of 0.68 pound. This indicates that the infected grain was distasteful and was eaten only because of necessity. However, none of the pigs became sick.

In 1935, as already pointed out, there was a severe epidemic of scab on barley and wheat in southern Minnesota. Barley fields with as much as 50 per cent kernel blight were observed, and fields with from 5 to 15 per cent kernel blight were not uncommon. The grain harvested from some of these fields was so severely infected that hungry swine refused to eat it. Samples of such grain were collected and fed to swine.

Table 6. Feeding Tests with Pigs, Using Diets of 10 Parts Tankage and 90 Parts Blighted Barley* from the 1933 Crop of Illinois, Minnesota, or Iowa

Feeding test or group number	Number of pigs used	Average weight of pigs at start (in lbs.)	Source of barley	Percentage blight by weight	Percentage seeds infected†			Duration of test in days‡	Average daily gain per pig (lbs.)	Average daily feed consumed per pig (lbs.)	Gain per pound of feed consumed
					Fusarium	*Helmintho-sporium*	Other fungi and bacteria				
22	3	40.5	Illinois	3.0	4.0	8.0	66.0	21	0.93	2.62	0.35
23	3	34.1	do	4.8	6.0	14.0	57.0	21	0.84	2.62	0.32
24	4	30.1	Minn.	4.8	2.0	6.0	75.0	21	0.63	2.49	0.26
25	3	53.5	do	3.0	2.0	12.0	65.0	26	0.99	3.32	0.40
26	3	51.1	Iowa	2.7	3.0	7.0	72.0	28	0.99	3.52	0.28
27	4	54.7	do	4.5	4.0	12.0	67.0	28	0.93	3.27	0.28

* Barley obtained through courtesy of Prof. J. G. Dickson of the University of Wisconsin, Madison, Wisconsin, and agent in Cereal Investigations, U.S.D.A.

† Based on plating 600 seeds on nutrient agar.

‡ Limited to amount of barley available.

Table 7. Feeding Tests with Pigs, Using Diets of 10 Parts Tankage and 90 Parts Clean Barley to Which Were Added Definite Amounts of Scabby Kernels

Feeding test or group number	Number pigs used	Average weight of pigs at start (in lbs.)	Percentage and type of barley (by weight)			Duration of test in days†	Average daily gain per pig (lbs.)	Average daily feed consumed per pig (lbs.)	Gain per pound of feed consumed
			Clean and heavy	Clean needles	Scabby*				
15	3	53.3	90	7.5	2.5	18	1.11	3.19	0.34
16	3	41.3	90	5.0	5.0	18	1.11	3.19	0.34
18	3	87.1	90	10.0	0.0	14	1.0	3.48	0.26
20	3	48.3	90	0.0	10.0	21	0.68	2.46	0.30

* Practically 100 per cent scabby kernels produced by artificial inoculation of barley under tents in the field, from which the heavy kernels were removed bv fanning.

† Limited to amount of barley available.

In the first test two pigs were induced to eat a few ounces of a mixture containing 25 parts corn and 75 parts barley with 32 per cent blight by weight. Both pigs became noticeably sick within 30 minutes and one vomited, the first cases under our experimental conditions in which immediate toxic effects were observed following voluntary ingestion of diseased barley. Three pigs were used in a second test. A mixture of 50 parts of diseased barley and 50 parts of a basal food mixture containing corn, alfalfa meal, tankage, and mineral supplements was fed them after a 24-hour fast period. After eating the mixture for only a few minutes, the pigs refused to eat more. They consumed only one-half pound of the mixture. In a few minutes they all appeared rather drowsy and languid, refusing to eat sound, healthy corn when it was offered. Only one of the pigs sickened enough to vomit. Similar results were obtained by feeding scabby wheat in the same proportion as barley.

To test the toxicity of moldy corn, a small pig was fed corn badly infected with *Fusarium graminearum* as a result of inoculating the growing ears. The pig, as in all other feeding tests, had been fasted for 24 hours before offering it the test feed. The ration consisted of 10 parts of the ground diseased corn and 90 parts basal food mixture. With reluctance it ate approximately one-fourth pound of the mixture over a period of about 15 minutes. About 10 minutes after it ceased eating, the toxic syndrome was observed, and during the next 90 minutes it vomited 8 times. It would appear from this and from the results obtained when water extracts of Fusarial-infected corn were administered that the toxic principle in corn may be even more potent than that produced in barley.

There seems to be a greater tendency for pigs to vomit when the scabby grain is fed as a mash rather than in the dry condition. Two pigs ate ¾ to 1 pound of mash consisting of 50 parts scabby barley (32 per cent scab by weight), 25 parts corn meal, and 25 parts powdered skimmed milk mixed thoroly with about one quart of water. Three other pigs were fed a similar ration, using scabby wheat instead of barley. The five pigs became sick and vomited several times within the next 45 minutes.

CLINICAL SYMPTOMS

The attitude and clinical symptoms of pigs fed scabby barley possessing potent toxic substances affords a striking picture. When such barley is offered swine for consumption they are very reluctant to eat it, even tho hungry. Oftentimes, pigs from which food has been withheld for 24 to 30 hours will refuse to eat the diseased barley. Other pigs may consume a few mouthfuls and then decline more. When clean sound corn, oats, or barley is mixed with toxic scabby barley and offered as food to hungry pigs, it is interesting to note how they attempt to pick out the sound grain and avoid as much as possible partaking of the diseased grain.

After pigs have eaten sparingly of toxic scabby barley, the following train of events is typical. The pig having consumed a relatively small amount of the toxic substance at the trough or feeder moves away from the grain and gives evidence of its desire to find other food. It may continue to hunt for something different to eat for several minutes, after which it stands or moves about in a semi-drowsy state and then lies down and appears doped and listless. Shortly it rises to its feet, moves about aimlessly, and lies down again. This may be repeated several times within 30 to 45 minutes, during which time either the symptoms become more exaggerated and vomition occurs or a return to normal ensues.

Emesis or vomition is the most observable characteristic symptom occurring in swine that have ingested a sufficient amount of the toxic substance to cause sickness. This syndrome is marked by successive and distinct phases. The pig first becomes restless. A vigorous twisting and rotating movement of the tail may occur intermittently followed by defecation or an attempt to defecate. It champs its jaws, grinds its teeth, and saliva drools from its mouth. Frequently it paws or scratches at its abdomen with its hind feet or rubs against the fence, trough, or other objects. The next phase is marked by retching. This is evidenced by spasmodic contractions and relaxations of the abdominal muscles and diaphragm. The contractions may be violent and forceful or only slight and, unless observed closely, will pass unnoticed. The more forceful retching symptoms are usually followed by the expulsion of vomitus. The number of times a pig vomits depends upon the amount and potency of the toxic substances ingested. As a rule it vomits 6 to 8 times during an hour. The intervals of time between successive vomitions are relatively short at first but may be as much as 20 to 30 minutes toward the last. Recovery usually occurs within 2 or 3 hours, and pigs will then again eat clean and sound foodstuff if it is available.

Some pigs seem to tolerate the scabby cereals better than others. Idiosyncrasies in the reaction of individual pigs to the consumption of the unsound food mixtures were very noticeable in many of the feeding tests. In general, it can be said pigs do not eat scabby grain with the relish and enjoyment characteristic of the species.

DETOXICATION OF WATER EXTRACTS OF SCABBY BARLEY

Results obtained in Germany (2) indicate that scabby barley may be rendered innocuous by prolonged storage in the open air and by repeated shoveling over in order to secure thoro aeration. It seemed probable that special treatments, such as the addition of certain materials to scabby barley, might render it less toxic and more suitable for animal food. A standard stock solution of an extract of scabby grain was made, and a number of different substances were added to samples of it. In all cases the liquid was administered to pigs orally via stomach tube. The substances tested, the different concentrations used, and the various methods employed are listed in Table 8. Under certain conditions, glucose, starch, flour, and milk had a tendency to reduce the toxic effect. When 25 grams of glucose were added to an extract made from 15 grams of scabby barley, the pigs did not vomit. One pig, however, vomited 3 times when only 10 grams of glucose were added, while the pig given the unadulterated extract vomited at least 9 times.

Table 8. Results of Various Tests to Counteract the Toxic Principle Present in Scabby Barley*

Number grams scabby barley	Material added	Weight of pig, lbs.	Time elapsed before vomiting, minutes	Number of times pig vomited
15	10 grams of glucose—boiled with extract just before feeding	50	32	3
15	25 grams of glucose—added at feeding time	50	.....	0
30	50 grams of glucose—added at feeding time	120	.....	0
15	25 grams of glucose—added at feeding time	60	.....	0
15	None	60	19	9
15	20 grams of starch—boiled with extract just before feeding	50	19	1
15	37½ grams of starch—added at feeding time	60	.....	0
30	50 grams of starch—added at feeding time	130	23	5
30	None	130	16	7
15	50 grams flour—added two days before feeding	50	.....	0
15	37½ grams flour—added at feeding time	50	43	4
30	30 grams flour—added 14 hours before feeding	130	.....	0
17	Extract from 50 grams of ground barley added 14 hours before feeding	60	31	11
15	None	50	14	12
15	50 cc. milk—added 2 days before feeding	50	.....	0
17	50 cc. milk—added 14 hours before feeding	60	41	4
17	50 cc. milk—added 14 hours before feeding	60	27	6
None	50 grams of clean barley—soaked 24 hours	50	.....	0

* Liquid contents administered per orum via stomach tube.

Flour, especially if added to the extract 14 to 48 hours before feeding, tended to counteract the toxic principle, but starch did not appear to be so effective. Boiling the starch in the extract of scabby barley appears to reduce the toxicity. Extracts from sound barley did not counteract the toxic principle, but perhaps the amount of barley used was too small or perhaps it did not stand long enough to be effective.

Tests indicated that the toxicity of the extracts may be reduced by the addition of skimmilk, especially if added two days before feeding. Obviously, milk will render toxic grain more palatable, but this is not necessarily a criterion of a reduction in toxicity.

Boiling the extract, either without pressure or in the autoclave under 15 pounds' pressure for 30 minutes, did not destroy the toxic principle. Likewise, cooking the scabby grain did not destroy it. Mains *et al.* (10) have obtained similar results.

Popp (15) found that soaking and washing the scabby grain in water tended to eliminate the toxic principle. This is in accord with the writers' results. However, the toxic principle is not readily removed from whole grains. For instance, 600 grams of scabby barley were soaked for six days in water and rinsed several times in clean water at the end of the second and fourth days. The extract made after the fifth and sixth days of soaking was administered to a pig, causing it to vomit three times within 30 minutes. On the other hand, the pig given the extract from the original soaking vomited 11 times within 50 minutes.

Observations on the effects of storage of scabby grain on its toxicity are somewhat conflicting. In one test the scab-infected barley (7.4 per cent by weight) was refused by pigs immediately after it had been ground but was eaten readily after about two months' storage in the open. Further tests, however, proved that the toxic principle may be retained for several years in whole scabby grain. Corn rotted by *Fusarium graminearum* was extremely toxic after being kept in a flour sack at room temperature for 14 months. A water extract made from 15 grams of scabby barley which had been stored for three years and two months in the laboratory was administered to a pig weighing about 20 pounds. The pig developed the symptoms of Fusarial poisoning and vomited 11 times within a half hour. Plating tests of the three-year-old diseased kernels proved that the *Fusaria* were dead. Apparently, the toxic principle can persist in the diseased grain longer than the living fungus.

DISCUSSION

In 1932 a serious situation arose with respect to the grading of barley. It was the practice at that time to classify barley containing a small amount of blighted kernels (not over 2 per cent) as "sample grade—scabby"[3]. The price paid for such barley was considerably less than that paid for barley without the stigma of "scab" attached to it, chiefly because such barley was considered unfit as food for pigs. Until recently it was not fully recognized that blight may be caused by a number of fungi other than *Fusarium* spp. It was shown by plating tests of diseased kernels that much of the blight in 1932, 1933, and 1934 was caused by *Alternaria, Helminthosporium,* and various other *Fungi Imperfecti.* Feeding tests with such barley containing as much as 31 per cent blighted kernels by weight indicated that it was not injurious to pigs, whereas in 1935 much of the barley was blighted by *Fusarium* and found to be unpalatable to pigs. Obviously, therefore, barley blighted by *Alternaria, Helminthosporium,* and fungi other than *Fusarium* should not be discounted on the market as heavily as that blighted by *Fusarium* spp.

It was shown that pigs will develop normally when fed sound barley to which has been added up to 5 per cent, by weight, of scabby kernels (infected with *Fusarium*). Pigs fed sound barley containing 10 per cent scabby kernels did not thrive, chiefly because they did not consume sufficient food. Therefore it seems likely that barley containing more than 5 per cent of typically scabbed kernels may prove injurious when fed to swine, because such samples also contain additional partially blighted kernels. However, no definite percentage can be given, since every sample differs from others in respect to its flora and percentage of partially blighted seed. There is a general tendency to harvest scabby grain before it matures. Apparently such practice may account for some of the variations in toxicity of lots of barley with similar percentages of blighted kernels. This may be explained by the fact that immature barley sometimes heats in the shock and this condition is conducive to rapid development of scab organisms and to the diffusion of the toxic principle even to non-infected kernels.

It is extremely difficult to determine by visual inspection the relative value of infected barley as feed for swine. A practical feeding test with animals is a more reliable index than a visual inspection or a plating test in the laboratory, unless the barley lot is conspicuously bad. The palatability of blighted grain may change from year to year, because many fungi are involved. Similarly, grain produced in the northern part of Minnesota is usually not toxic to pigs, because it usually is blighted chiefly by harmless fungi, while that from the southern part is more apt

[3] In 1933, and again in 1934, there were revisions of the grain standards, the word "scabby" was dropped, and the word "blighted" was added to the grade designation. The tolerance of blighted kernels was liberalized in the various grades. The revised order now reads: "Blighted barley" shall be all barley which contains more than 4 per cent of barley damaged or materially discolored by blight and/or mold (23).

to be harmful because it is likely to contain considerable blight caused by the toxic *Fusaria*.

As an aid in clinical diagnosis, a study was made of the symptoms resulting from feeding toxic grain. Pigs fed extract from Fusarium-infected corn sickened and in two instances died. Vomiting was the most characteristic symptom observed. However, vomition induced by the toxic principle should not be construed as pathognomic of the toxicity of scabby barley alone, as vomiting also is an act on the part of the animal to combat any toxic principle that may become very injurious and even lead to its death.

Barley that is unpalatable and toxic to pigs should either not be fed at all or only after mixing with sound grain and in such proportion that pigs will consume normal amounts of the mixture. Since other grains also may be infected with scab, considerable care should be taken in selecting the grain used in making the mixture. It is significant that mixing badly scabbed barley with milk and other palatable food may prove more harmful than beneficial, because the pigs will consume more toxic grain than otherwise. It seems likely that very badly scabbed grain can not be fed economically to pigs, even tho mixed with other food in such proportion that there are no obviously injurious effects.

The danger of feeding scabby barley can be reduced somewhat by removing some of the light and blighted kernels by fanning or by immersing the grain in water and skimming off the kernels that float. It is generally considered that scabby barley can be fed safely to sheep and cattle, especially if mixed with other grains, but there still is urgent need for a study of the best method of utilizing it, especially as a concentrate for swine.

SUMMARY

1. Many different species of fungi and bacteria are associated with blighted barley. *Alternaria, Helminthosporium,* and *Fusarium* were the most common fungi isolated.

2. In Minnesota, there were striking differences in the prevalence of these fungi on different lots of blighted barley from different localities in the same year and also from the same locality in different years. Barley distinctly blighted by *Fusarium* (scabby) came from the southern part of the state only.

3. The relative toxicity of different lots of grain was determined by making a water extract and administering it to pigs orally via stomach tube. An extract of 15 grams (about ½ oz.) of scabby kernels was sufficient to make a pig weighing 100 pounds vomit. Sterile extracts made from scabby barley and injected intravenously and intraperitoneally caused the pigs to sicken.

4. Extracts from pure cultures of *Fusarium* spp. grown on various substrata were not toxic to pigs. However, pure cultures of *Fusarium, Alternaria, Chaetomium,* and *Penicillium, Helminthosporium,* and bacteria, when grown on steamed barley, were refused by pigs unless mixed with other food.

5. It was demonstrated by feeding tests with pigs that *Fusarium graminearum* produces a toxic principle in wheat, barley, and corn if inoculated at time of grain formation.

6. The toxic principle may persist in whole barley for at least three years. It is water-soluble and thermostable.

7. The amount of toxic principle present in scabby barley usually is proportional to the degree of shriveling. Many of the most toxic kernels can be removed by fanning thoroly or by immersing the grain in water and then skimming off the blighted seeds that float on the surface.

8. Feeding tests were made with 23 lots of barley graded either scabby or blighted and with five lots of sound barley (controls). Barley blighted primarily with *Helminthosporium* and *Alternaria* was not toxic to pigs, altho it contained as much as 31 per cent by weight of blighted kernels. The feeding value of barley was reduced considerably when 10 per cent of scabby kernels were added to sound barley. Barley naturally infected with 16 per cent scab was extremely toxic to pigs, while pigs refused to eat barley with 32 per cent scab infection by weight.

9. Pigs affected with Fusarium poisoning lose their appetites, become listless, weak, sometimes vomit, and may even die. An overdose of an extract of Fusarium-infected corn caused the death of two pigs.

10. There is some indication that the toxic extract of scabby barley may be somewhat detoxicated under certain conditions by the addition of milk, starch, and other materials. Some of the toxic principle can be removed by soaking and washing the infected grain.

11. These investigations indicate the need for further information on the utilization of scabby barley as feed for swine.

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